# CHROMOSOME NUMBERS AND INCIDENCE OF POLYPLOIDY IN PANICOIDEAE (POACEAE) FROM PAKISTAN[1]

*S. M. Nadeem Ahsan,[2] Ahsan A. Vahidy,[3] and S. I. Ali[2]*

## ABSTRACT

Chromosome numbers in 126 accessions representing 58 taxa belonging to 27 genera of Panicoideae from Pakistan are reported. Chromosome numbers of three species viz. *Panicum atrosanguineum* ($n = 18$), *Pennisetum lanatum* ($n = 18$), and *Elionurus royleanus* ($n = 10$) are new determinations. New cytotypes are reported for *Isachne himalaica* (tetraploid) and *Setaria intermedia* (tetraploid). Chromosomal counts for 30 other species are new to the flora of Pakistan. More than two-thirds of the species investigated were found to be polyploid in nature.

Members of Poaceae have been of great interest from both evolutionary and cytotaxonomic points of view. The role of polyploidy in the evolution and diversification of grasses has been exceptionally large. Nearly all genera and a majority of species in this family possess chromosome numbers which are multiple of the original basic number. According to Stebbins (1950, 1956), polyploidy has played an important role in the production of a wide range of chromosome numbers in grasses. Further, he estimated nearly 70–75% of grass species to be polyploid. Sharma (1985) estimated 63.41% polyploidy in the Himalayan grasses. Baquar (1976) observed only 30.40% polyploidy among members of the family Poaceae from Pakistan. In the present study the level of polyploidy is discussed in the light of available information about the chromosome counts of Panicoideae from Pakistan.

## MATERIALS AND METHODS

For meiotic preparations young, unopened inflorescences were fixed in 1:3 acetic alcohol and stored at −4°C, and the anthers were squashed in 1.8% aceto-orcein. For mitotic preparations young and healthy root tips from germinating seeds were pretreated with 0.002 M 8-hydroxyquinoline for 4–6 hr., fixed in acetic alcohol (1:3) for 1 hr., hydrolysed in 1 N HCl for 6–12 min. at 60°C, and squashed in 1.8% aceto-orcein. The slides were analyzed and photographs were taken before making them permanent in euparal or Canada balsam.

## OBSERVATIONS AND RESULTS

Table 1 lists chromosome numbers for 126 records representing 58 taxa of 27 genera. Counts new to science and new to the flora of Pakistan are specified on the basis of survey of IPCN (Fedorov, 1974; Goldblatt, 1981, 1984, 1985, 1988; Moore, 1973, 1974; Ornduff, 1967). Ploidy level was inferred from the lowest known diploid number in the genus.

Out of a total of 58 taxa investigated, 39 (67.24%) were found to be polyploid. The majority of the polyploids were at the tetraploid level. Only eight hexaploids, five octoploids and one decaploid taxa were observed.

In Table 1 the genera are arranged in tribes following Cope (1982), and the species are arranged alphabetically within genera. Voucher specimens, identified with the help of Flora of Pakistan (Cope, 1982), are deposited in Karachi University Herbarium (KUH).

## DISCUSSION

The investigated species belong to three tribes of Panicoideae. In Pakistan the tribe Isachneae is represented by a single species, *Isachne himalaica* (Fig. 19). Previously the pentaploid of this species with $2n = 50$ was reported by Mehra (1982) and Parkash (1979). The report presented here is the first of a tetraploid ($n = 20$) cytotype in this species.

The tribe Paniceae is one of the largest tribes

[1] We thank M. Qaiser and Z. A. Razaq of Department of Botany, University of Karachi, for their help in identification of vouchers. We also thank A. Ghafoor, S. Omer, T. Ali, Z. A. Razaq, Moinuddin, and B. Jahan of the Department of Botany, University of Karachi, for collecting cytological material. This paper is part of the work supported by National Science Foundation grant INT 8510318.

[2] Department of Botany, University of Karachi, Karachi-75270, Pakistan.

[3] Department of Genetics, University of Karachi, Karachi-75270, Pakistan.

TABLE 1. Chromosome numbers and ploidy level in taxa of Panicoideae (Poaceae) from Pakistan. K.U. = Karachi University. D. G. Khan = town of Dera Ghazi Khan.

| Taxon | Chromosome no. *n* | Ploidy level | Voucher |
|---|---|---|---|
| Tribe Isachneae | | | |
| **Isachne himalaica* Hook. f. (Fig. 19) | 20 | Tetraploid | Sargodha: *Ghafoor 3848* |
| Tribe Paniceae | | | |
| **Brachiaria deflexa* (Schumach.) C. E. Hubbard ex Robyns (Fig. 1) | 18 | Tetraploid | Hazara: *Omer 2222*; Dir: *Ghafoor 2331*; D. G. Khan: *Ghafoor 3692* |
| **Brachiaria eruciformis* (Sm.) Stapf | 9 | Diploid | K.U. Campus: *Ahsan 65*; Soon Sakesar: *T. Ali 1730* |
| *Brachiaria ramosa* (L.) Stapf | 18 | Tetraploid | K.U. Campus: *Jahan 57* |
| *Brachiaria ramosa* (Fig. 2) | 36+3B | Octoploid | K.U. Campus: *Jahan 58* |
| **Brachiaria reptans* (L.) Gardner & Hubbard (Fig. 3) | 7 | Diploid | K.U. Campus: *Ahsan 78, Moin. 48, Razaq 128*; Head Rajkan: *Ghafoor 3523* |
| *Cenchrus biflorus* Roxb. (Fig. 4) | 17 | Aneuploid | K.U. Campus: *Ahsan 44* |
| *Cenchrus biflorus* | 16 | Aneuploid | Mianwali: *T. Ali 1811* |
| **Cenchrus ciliaris* L. | 18 | Diploid | Layyah: *Ghafoor 3747*; D. G. Khan: *Ghafoor 3625* |
| *Cenchrus ciliaris* | 17 | Aneuploid | K.U. Campus: *Razaq 133*; Makran: *T. Ali 835*; Attock: *Ghafoor 2268* |
| *Cenchrus pennisetiformis* Hochst. & Steud. ex Steud. | 18 | Diploid | K.U. Campus: *Siddiqui 2* |
| *Cenchrus setigerus* Vahl | 17 | Aneuploid | Safari Park, Karachi: *Siddiqui 63*; D. G. Khan: *Ghafoor 3603*; Mianwali: *T. Ali 1824*; Darsanochano: *Siddiqui 88*; K.U. Campus: *Siddiqui 50*; Kathore: *Jahan 66, 78*; Manghopir: *Razaq 159* |
| **Digitaria ciliaris* (Retz.) Koeler | 27 | Hexaploid | K.U. Campus: *Siddiqui 32*; *Razaq 146* |
| *Digitaria ciliaris* | 36 | Octoploid | Kashmir: *T. Ali 20* |
| **Digitaria nodosa* Parl. (Fig. 5) | 9 | Diploid | K.U. Campus: *Moin. 68* |
| **Digitaria setigera* Roth ex Roem. & Schult. | 36 | Octoploid | Hazara: *Omer 2739* |
| **Digitaria stricta* Roth ex Roem. & Schult. | 18 | Tetraploid | Pail: *Ghafoor 3791* |
| *Echinochloa colona* (L.) Link | 9 | Diploid | Dir: *Ghafoor 4093* |
| *Echinochloa colona* | 18 | Tetraploid | K.U. Campus: *Jahan 20* |
| *Echinochloa colona* | 27 | Hexaploid | Kashmir: *T. Ali 400*; Makran: *T. Ali 836*; Zhob: *T. Ali 1087*; K.U. Campus: *Ahsan 7*; Baltistan: *Omer 2539* |
| **Echinochloa crus-galli* (L.) P. Beauv. | 27 | Hexaploid | Kashmir: *T. Ali 46* |
| *Echinochloa crus-galli* (Fig. 20) | 45 | Decaploid | Thatta: *Siddiqui 153* |
| **Echinochloa frumentacea* Link | 27 | Hexaploid | Khushab: *Ghafoor 3796* |
| **Eriochloa fatmensis* (Hochst. & Steud.) W. D. Clayton | 9 | Diploid | K.U. Campus: *Moin. 52* |
| *Eriochloa fatmensis* | 18 | Tetraploid | K.U. Campus: *Ahsan 53* |
| **Eriochloa procera* (Retz.) C. E. Hubbard | 9 | Diploid | K.U. Campus: *Moin. 49, 50* |
| *Eriochloa procera* | 18 | Tetraploid | Sajawal: *Ahsan 21*; Thatta: *Siddiqui 121* |
| *Panicum antidotale* Retz. | 9 | Diploid | K.U. Campus: *Razaq 123* |
| ***Panicum atrosanguineum* Hochst. ex A. Rich. (Fig. 6) | 18 | Tetraploid | Khushab: *Ghafoor 3823* |
| **Panicum maximum* Jacq. (Fig. 7) | 9 | Diploid | Hasilpur: *Ghafoor 3584*; Mianwali: *T. Ali 1816* |
| **Panicum miliaceum* L. | 18 | Tetraploid | Bahawalpur: *Ghafoor 3528* |
| **Panicum repens* L. (Fig. 8) | 9 | Diploid | Makran: *Omer 2165* |

TABLE 1. Continued.

| Taxon | Chromosome no. *n* | Ploidy level | Voucher |
|---|---|---|---|
| **Panicum turgidum* Forssk. | 9 | Diploid | Makran: *T. Ali 855*; K.U. Campus: *Siddiqui 41*; * Kashmir: *T. Ali 128* |
| **Paspalidium flavidum* (Retz.) A. Camus | 27 | Hexaploid | Rawalpindi: *Ghafoor 4152* |
| *Paspalidium geminatum* (Forssk.) Stapf (Fig. 9) | 9 | Diploid | K.U. Campus: *Moin. 69, 59* |
| **Paspalum dilatatum* Poir. | 30 | Hexaploid | Gilgit: *Omer 2591, 2271*; Rawalpindi: *Ghafoor 4176* |
| **Paspalum paspalodes* (Michx.) Scribner (Fig. 10) | 30 | Hexaploid | K.U. Campus: *Jahan 40, 41*; Swat: *Ghafoor 3334*; Sukkur: *Ghafoor 3492*; Thatta: *Siddiqui 132* |
| **Pennisetum flaccidum* Griseb. | 27 | Hexaploid | Dir: *Ghafoor 2408* |
| **Pennisetum glaucum* (L.) R. Br. | 7 | Diploid | K.U. Campus: *Moin. 73* |
| ***Pennisetum lanatum* Klotzsch (Fig. 11) | 18 | Tetraploid | Swat: *Ghafoor 3429* |
| **Pennisetum orientale* Rich. | 9 | Diploid | Soon Sakesar: *T. Ali 1624* |
| *Pennisetum orientale* (Fig. 12) | 18 | Tetraploid | Makran: *T. Ali 1006* |
| *Setaria intermedia* Roem. & Schult. (Fig. 21) | 18 | Tetraploid | K.U. Campus: *Ahsan 76* |
| **Setaria pumila* (Poir.) Roem. & Schult. | 36 | Octoploid | Vehari: *Ghafoor 3598*; Chitral: *Ghafoor 2493* |
| **Setaria verticillata* (L.) P. Beauv. | 9 | Diploid | K.U. Campus: *Moin. 70*; Safari Park, Karachi: *Siddiqui 72* |
| Tribe Andropogoneae | | | |
| *Apluda mutica* L. | 10 | Diploid | D. G. Khan: *Ghafoor 3711* |
| **Arthraxon lancifolius* (Trin.) Hochst. | 9 | Diploid | Kashmir: *T. Ali 194* |
| *Arthraxon prionodes* (Steud.) Dandy (Fig. 14) | 18 | Tetraploid | Soon Sakesar: *T. Ali 1724, 1701* |
| *Arthraxon prionodes* (Fig. 13) | 10 | Aneuploid | Hazara: *Omer 2265* |
| *Bothriochloa ischaemum* (L.) Keng | 20 | Tetraploid | Gilgit: *Omer 2617*; Chitral: *Ghafoor 3218* |
| *Capillipedium parviflorum* (R. Br.) Stapf | 20 | Tetraploid | Kashmir: *T. Ali 266* |
| *Chrysopogon aucheri* (Boiss.) Stapf | 10 | Diploid | K.U. Campus: *Moin. 1*; Safari Park, Karachi: *Siddiqui 67*; Kathore: *Jahan 86*; Makran, *T. Ali 830* |
| *Chrysopogon gryllus* (L.) Trin. subsp. *echinulatus* (Nees) T. A. Cope | 10 | Diploid | Swat: *Ghafoor 3431* |
| *Chrysopogon serrulatus* Trin. (Fig. 15) | 10 | Diploid | Hazara: *Omer 2267* |
| *Cymbopogon jwarancusa* (Jones) Schult. | 20 | Tetraploid | Safari Park, Karachi: *Siddiqui 73*; K.U. Campus: *Jahan 55*; Choa Sayyadan Shah: *T. Ali 1872* |
| **Cymbopogon martinii* (Roxb.) W. Watson | 20 | Tetraploid | Kashmir, *T. Ali 207* |
| *Dichanthium annulatum* (Forssk.) Stapf | 20 | Tetraploid | Kashmir: *T. Ali 14*; Attock: *Ghafoor 2275*; *Ghafoor 2276*; K.U. Campus: *Moin. 4, Jahan 54* |
| *Dichanthium foveolatum* (Delile) Roberty (Fig. 16) | 20 | Tetraploid | K.U. Campus: *Ahsan 57*; Kasmir: *T. Ali 35*; Attock: *Ghafoor 4232* |
| ***Elionurus royleanus* Nees ex A. Rich. (Fig. 17) | 10 | Tetraploid | K.U. Campus: *Moin. 65* |
| **Hackelochloa granularis* (L.) Kuntze | 7 | Diploid | K.U. Campus: *Ahsan 30* |

TABLE 1. Continued.

| Taxon | Chromosome no. *n* | Ploidy level | Voucher |
|---|---|---|---|
| *Heteropogon contortus* (L.) P. Beauv. ex Roem. & Schult. (Fig. 22) | 10 | Diploid | Pail: *Ghafoor 3858*; K.U. Campus: *Moin. 38* |
| *Heteropogon contortus* | 20 | Tetraploid | Kashmir: *T. Ali 32* |
| *Lasiurus scindicus* Henr. | 9 | Diploid | Cholistan: *Ghafoor 3545*; Makran: *T. Ali 829; Omer 2117*; K.U. Campus: *Razaq 167, Siddiqui 46* |
| *Phacelurus speciosus* (Steud.) C. E. Hubbard | 10 | Diploid | Chitral: *Ghafoor 2705* |
| *Saccharum griffithii* Munro ex Boiss. (Fig. 23) | 10 | Diploid | D. G. Khan: *Ghafoor 3616* |
| *Saccharum spontaneum* L. (Fig. 24) | 27 | Aneuploid | Sargodha: *T. Ali 1667* |
| **Sorghum bicolor* (L.) (Fig. 18) | 10 | Tetraploid | Makran: *Omer 2043* |
| *Sorghum halepense* (L.) Pers. | 20 | Octoploid | Chitral: *Ghafoor 3215*; Muzaffargarh: *Ghafoor 3757*; Chakwal: *Ghafoor 4247*; K.U. Campus: *Jahan 38* |
| *Vetiveria zizanioides* (L.) Nash | 10 | Diploid | Sialkot: *Ghafoor 4310* |
| **Zea mays* L. | $2n = 20$ | Diploid | Darsanochano: *Siddiqui 94* |

* Count new to flora of Pakistan.
** Count new to science.

of the grass family. In Pakistan it is represented by 15 genera and 73 species (Cope, 1982). Species of 11 of these genera were studied. *Brachiaria reptans* with $n = 7$ (Fig. 3) and *B. eruciformis* with $n = 9$ are diploids based on $x = 7$ and 9 respectively. These counts are new to the flora of Pakistan and conform with earlier counts reported from other regions (Malik & Mary, 1970; Christopher & Abraham, 1976; Basappa & Muniyamma, 1981; Mehra, 1982). *Brachiaria deflexa*, with $n = 18$ (Fig. 1), is tetraploid on the basis of $x = 9$. In *B. ramosa* we observed three B-chromosomes in addition to 36 bivalents.

Both $n = 17$ and $n = 18$ are recorded in the genus *Cenchrus*. As far as the basic number is considered, Löve and Löve (1961) regarded $x = 17$ as the basic number, while Baquar and Anjum (1969) regarded $x = 9$ as the basic number. Though $n = 9$ is found in other genera of the tribe, $n = 9$ is hitherto unknown in the genus *Cenchrus*. Therefore, in our opinion, the basic number for this genus is $x = 18$, reflecting an early tetraploid origin, and $x = 17$ is an aneuploid descendant from $x = 18$.

A new chromosome count for *Panicum atrosanguineum* ($n = 18$, Fig. 6) revealed that it is a tetraploid species.

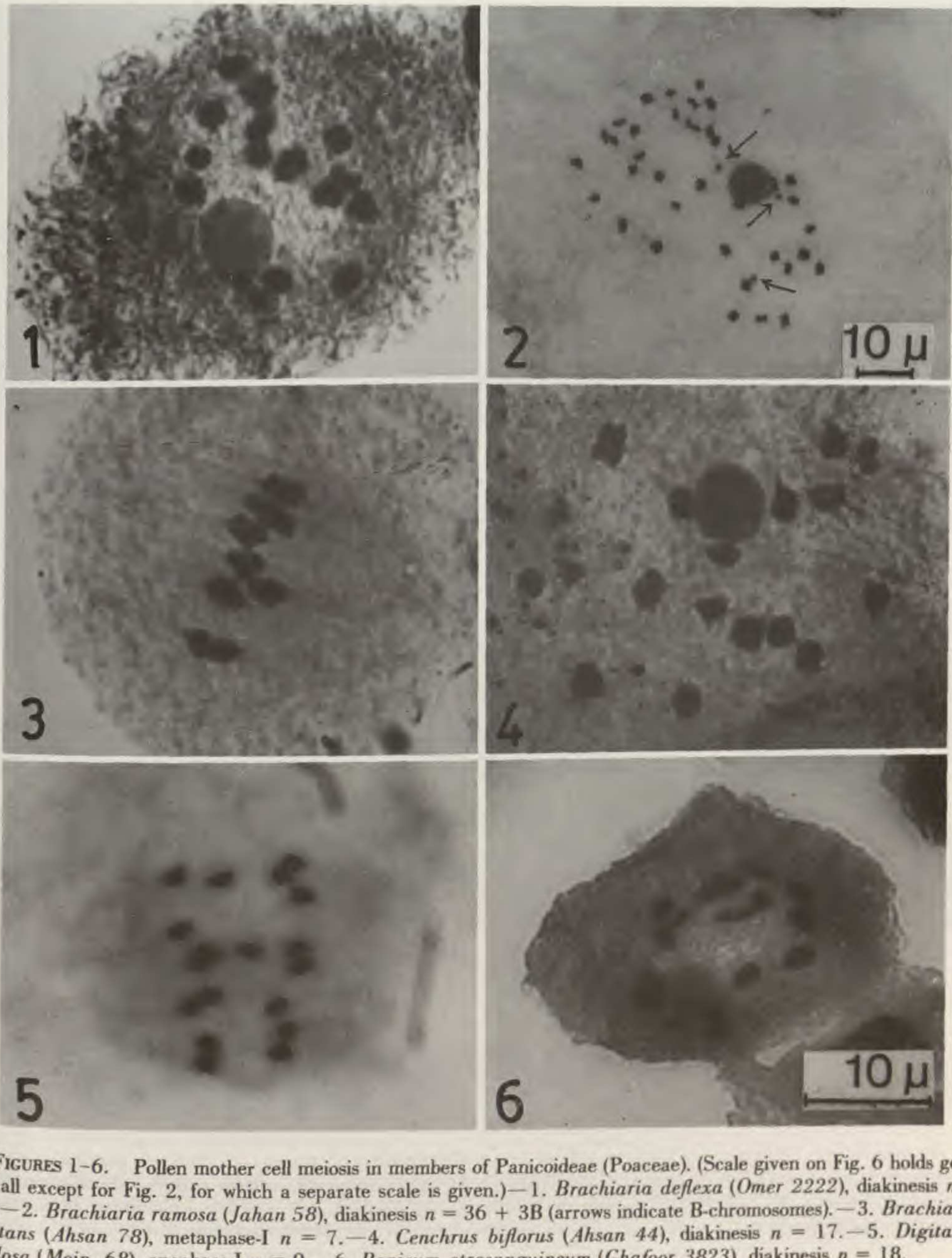
*Pennisetum* is agronomically an important genus, with $n = 7$ and $n = 9$. *Pennisetum lanatum* (Fig. 11) has been reported for the first time to be tetraploid ($n = 18$).

The base number for the genus *Setaria* is $x = 9$. In the present study three species, namely, *S. intermedia* ($n = 18$; Fig. 21), *S. pumila* ($n = 36$), and *S. verticillata* ($n = 9$) show great cytological variability. Baquar and Saeed (1969) reported $n = 9$, while Raman et al. (1959) reported $n = 27$ for *S. intermedia*, but we are reporting a new ploidy level, i.e., $n = 18$, for the same species.

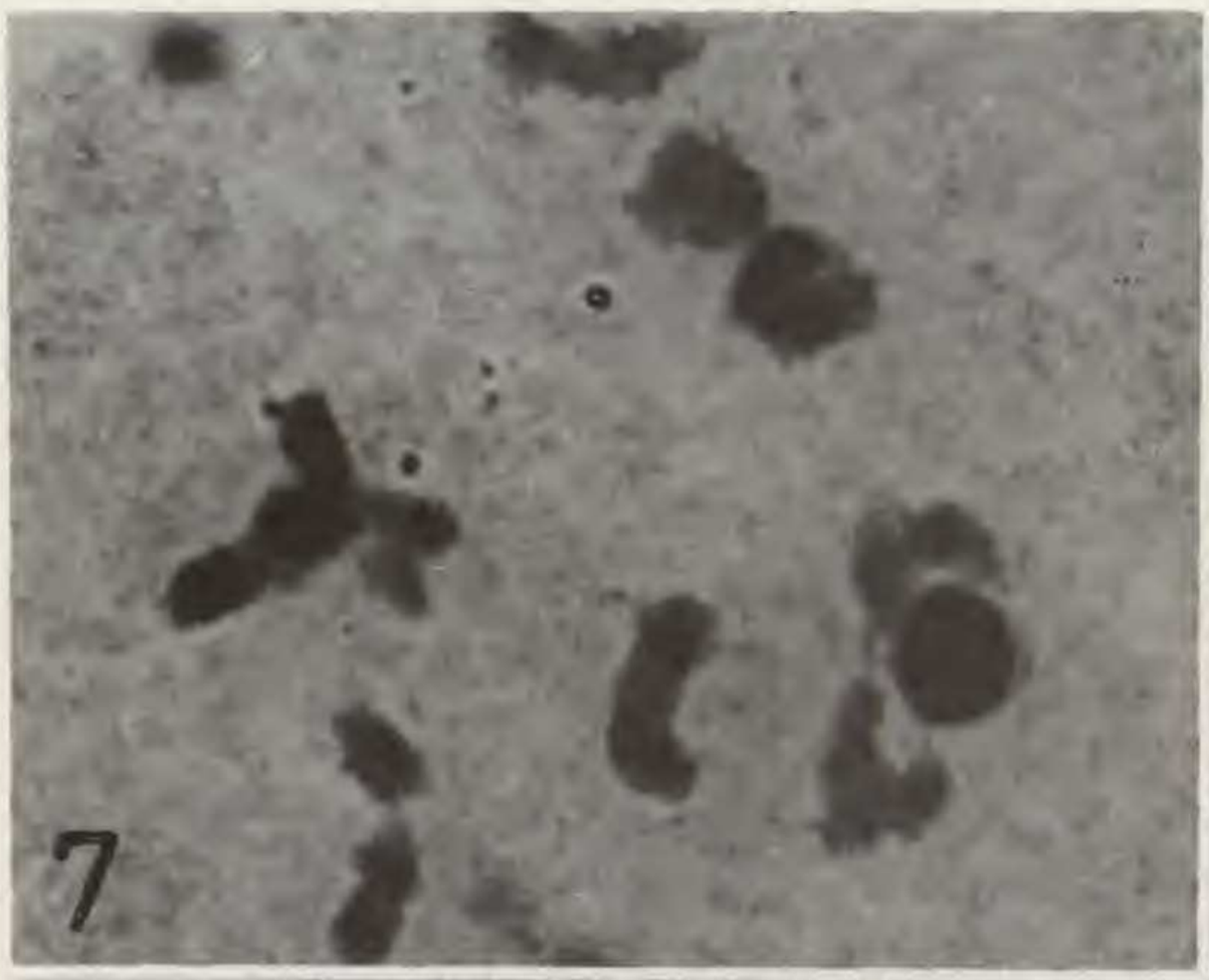
In Pakistan the tribe Andropogoneae is represented by 36 genera and 67 species (Cope, 1982). In the present study, species belonging to 17 genera of the tribe have been investigated cytologically. In *Arthraxon prionodes*, $n = 10$ (Fig. 13) and $n = 18$ (Fig. 14) are reported here, numbers which may be hyperaneuploid and tetraploid with respect to the basic number, $x = 9$.

The chromosome count for *Elionurus royleanus* (Fig. 17) is reported here for the first time. We believe that it is a tetraploid species ($n = 10$). This is substantiated by the report (Dujardin, 1978) that *E. hesii* has $n = 5$.

The basic number for the genus *Lasiurus* is $x = 9$. The present and previous reports (Faruqi et al., 1979) both indicate the presence of only diploid populations in Pakistan, whereas the count given




FIGURES 1–6. Pollen mother cell meiosis in members of Panicoideae (Poaceae). (Scale given on Fig. 6 holds good for all except for Fig. 2, for which a separate scale is given.)—1. *Brachiaria deflexa* (*Omer 2222*), diakinesis $n$ = 18.—2. *Brachiaria ramosa* (*Jahan 58*), diakinesis $n = 36 + 3B$ (arrows indicate B-chromosomes).—3. *Brachiaria reptans* (*Ahsan 78*), metaphase-I $n = 7$.—4. *Cenchrus biflorus* (*Ahsan 44*), diakinesis $n = 17$.—5. *Digitaria nodosa* (*Moin. 68*), anaphase-I $n = 9$.—6. *Panicum atrosanguineum* (*Ghafoor 3823*), diakinesis $n = 18$.

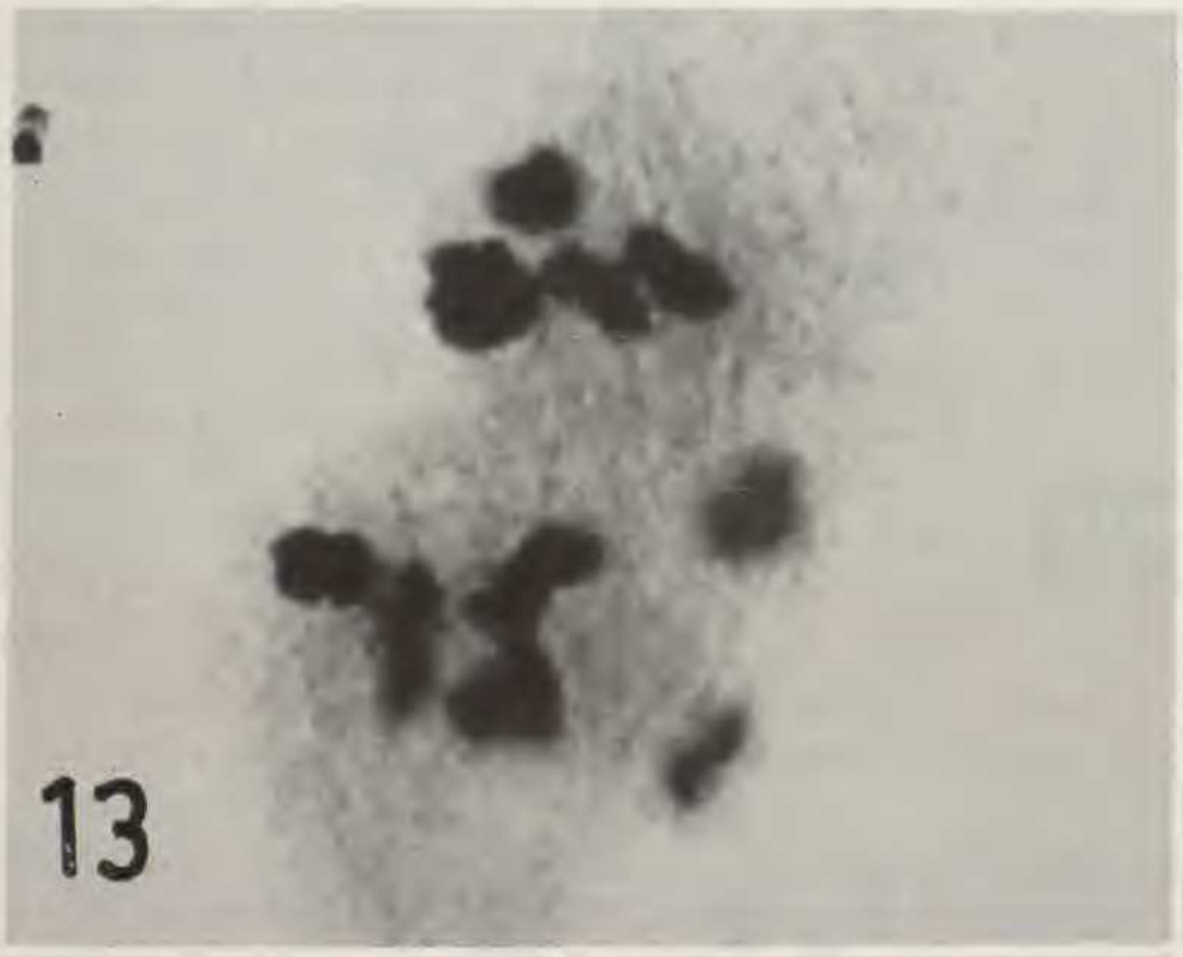


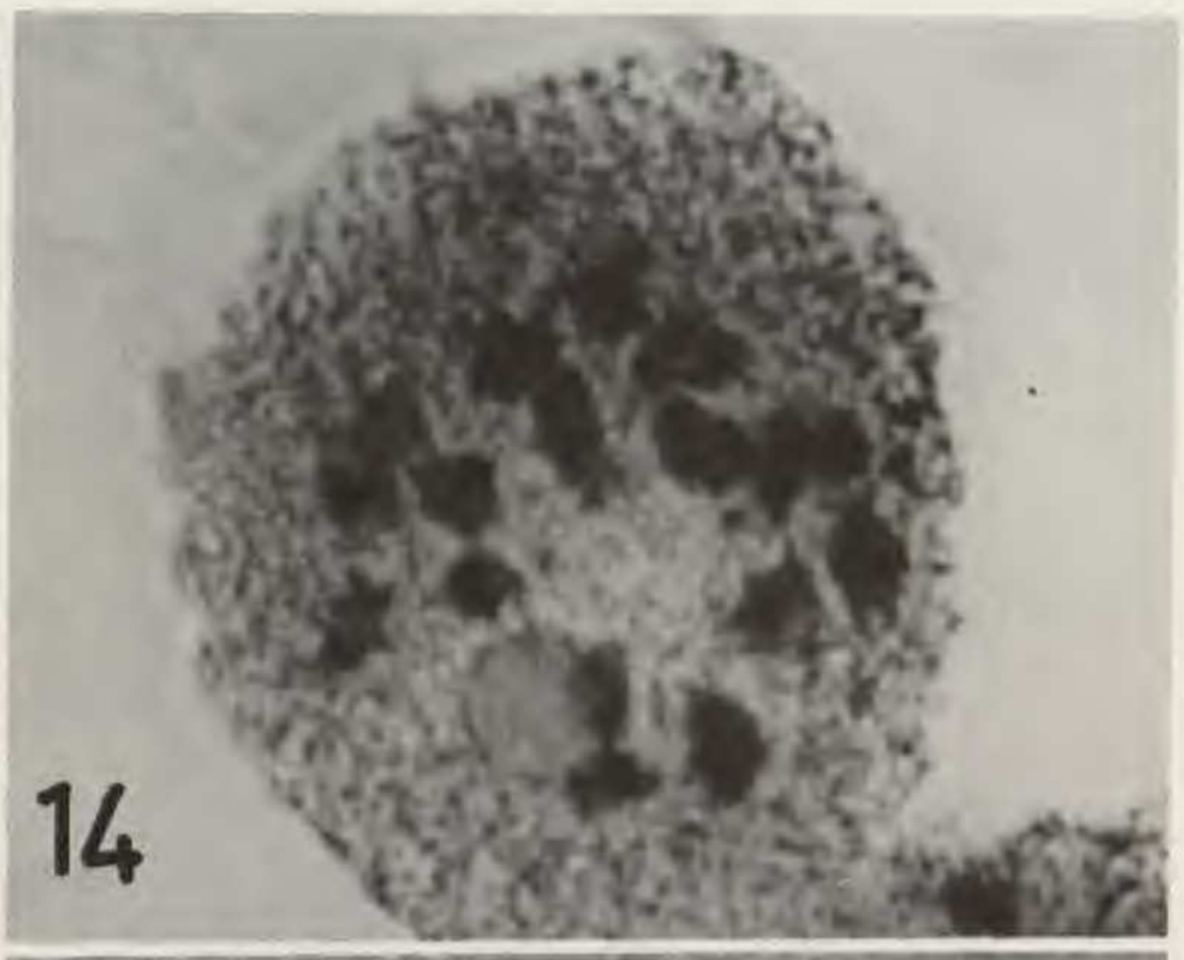




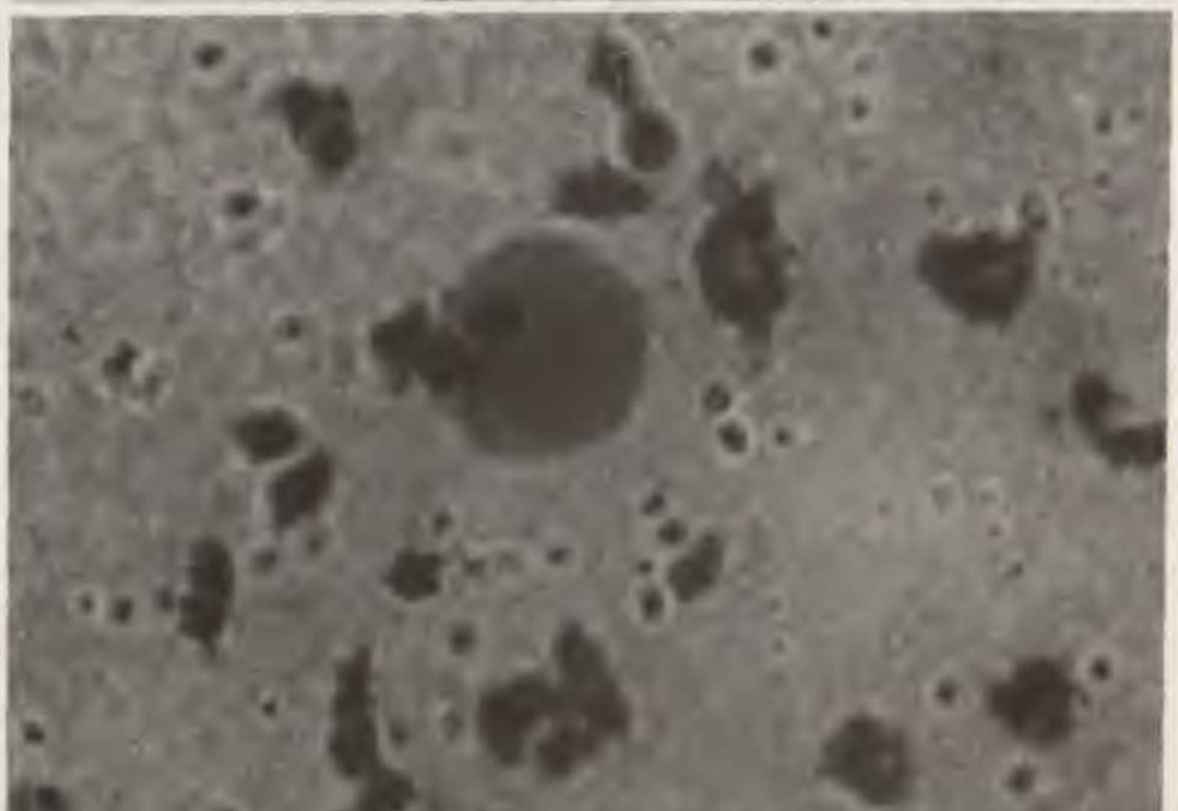


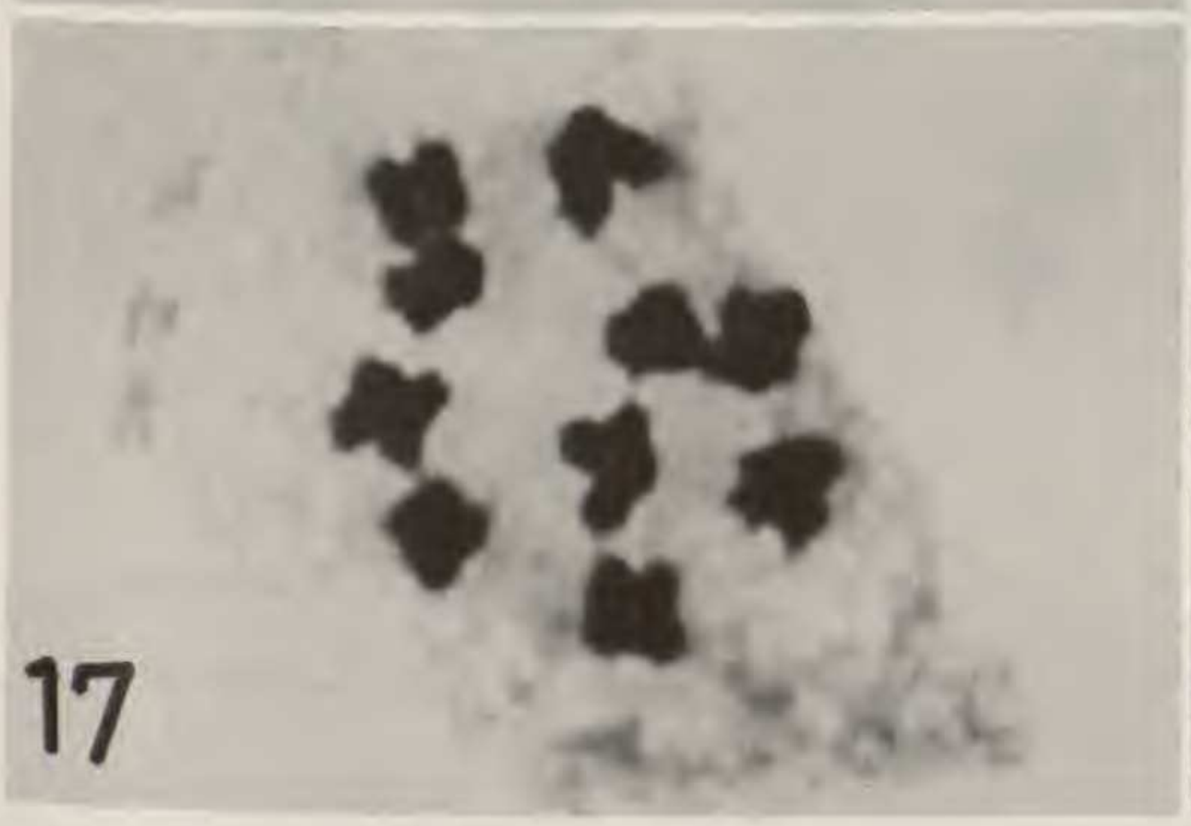
FIGURES 7–12. Pollen mother cell meiosis in members of Panicoideae (Poaceae).—7. *Panicum maximum* (*Ghafoor 3584*), diakinesis $n = 9$.—8. *Panicum repens* (*Omer 2165*), diakinesis $n = 9$.—9. *Paspalidium geminatum* (*Moin. 69*), diakinesis $n = 9$.—10. *Paspalum paspalodes* (*Jahan 40*), metaphase-I $n = 30$.—11. *Pennisetum lanatum* (*Ghafoor 3429*), diakinesis $n = 18$.—12. *Pennisetum orientale* (*T. Ali 1006*), diakinesis $n = 18$.



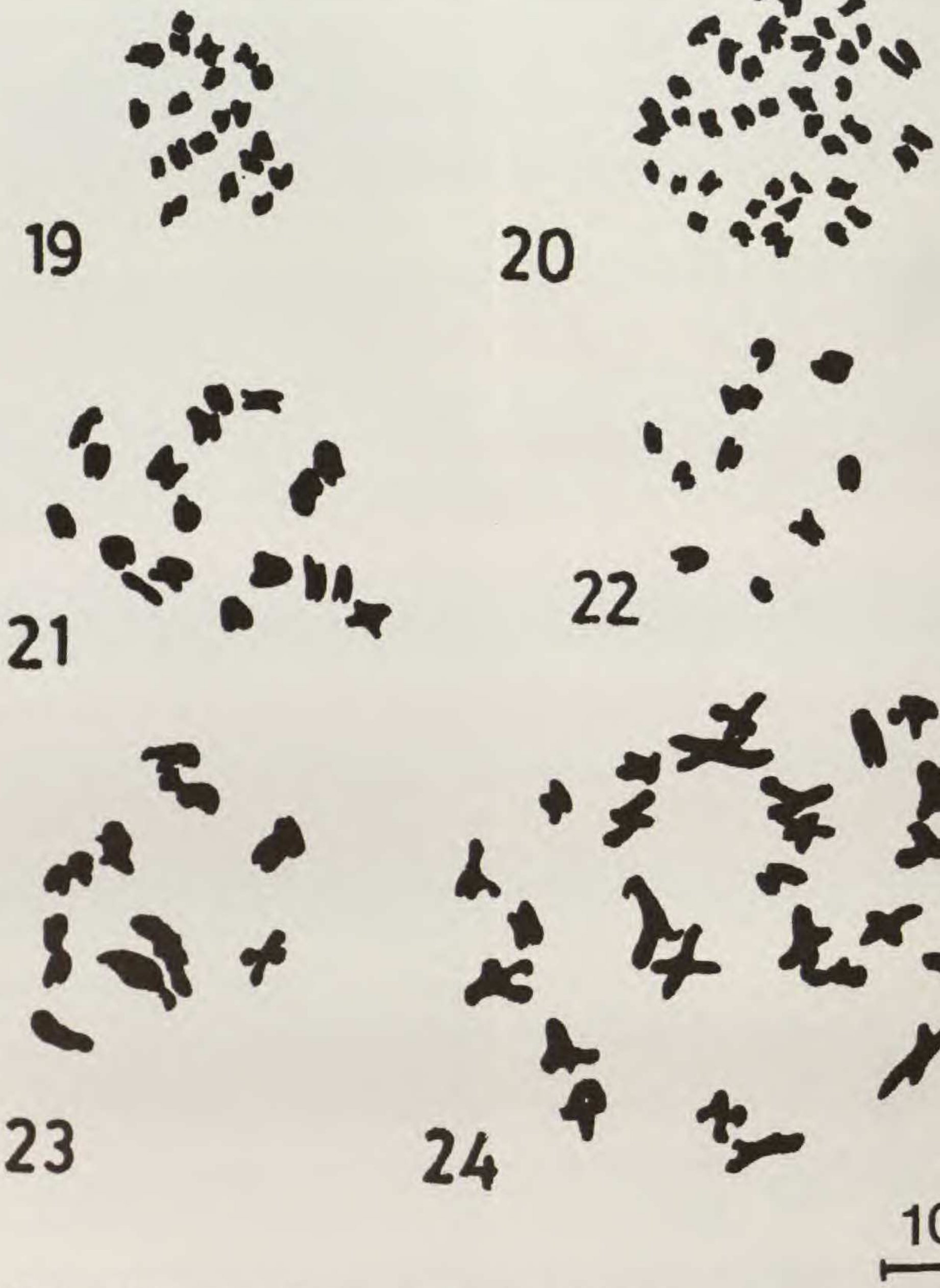






FIGURES 13–18. Pollen mother cell meiosis in members of Panicoideae (Poaceae).—13. *Arthraxon prionodes* (*Omer 2265*), metaphase-I $n = 10$.—14. *Arthraxon prionodes* (*T. Ali 1724*), diakinesis $n = 18$.—15. *Chrysopogon serrulatus* (*Omer 2267*), diakinesis $n = 10$.—16. *Dichanthium foveolatum* (*Ahsan 57*), diakinesis $n = 20$.—17. *Elionurus royleanus* (*Moin. 65*), metaphase-I $n = 10$.—18. *Sorghum bicolor* (*Omer 2043*), metaphase-I $n = 10$.




FIGURES 19–24. Pollen mother cell meiosis in members of Panicoideae (Poaceae).—19. *Isachne himalaica* (*Ghafoor 3848*), metaphase-I $n = 20$.—20. *Echinochloa crus-galli* (*Siddiqui 153*), diakinesis $n = 45$.—21. *Setaria intermedia* (*Ahsan 76*), diakinesis $n = 18$.—22. *Heteropogon contortus* (*Ghafoor 3858*), diakinesis $n = 10$.—23. *Saccharum griffithii* (*Ghafoor 3616*), diakinesis $n = 10$.—24. *Saccharum spontaneum* (*T. Ali 1667*), diakinesis $n = 27$.

by Celarier (1957) indicates the presence of aneuploidy at hexaploid level.

The present investigation of polyploidy in Panicoideae from Pakistan demonstrates a prevalence of eupolyploidy as well as aneuploidy. From the total of 58 taxa cytologically studied, only 26 were diploids while the rest of the species were either aneuploids or eupolyploids. The common ploidy levels were tetraploid and hexaploid, though, rarely, octoploid and decaploid levels were also observed.

## LITERATURE CITED

BAQUAR, S. R. 1976. Polyploidy in the Flora of Pakistan in relation to latitude, life form and taxonomic groups. Taxon 25: 621–627.

——— & V. ANJUM. 1969. Chromosome behaviour in *Cenchrus* complex from southern West Pakistan. Portugaliae Acta Biologica XI(3–4): 288–296.

——— & M. SAEED. 1969. Chromosome studies and polyploid analysis in grasses of West Pakistan I. Caryologia 22: 103–112.

BASAPPA, G. P. & M. MUNIYAMMA. 1981. Chromosome Number Reports LXXII. Taxon 30: 703.

CELARIER, R. P. 1957. Cytotaxonomy of the Andro-

pogoneae. II. Subtribes Ischaemineae, Rottboelliinae, and the Maydeae. Cytologia 22: 160–183.

CHRISTOPHER, J. & A. ABRAHAM. 1976. Studies on the cytology and phylogeny of south Indian grasses. III. Subfamily VI: Panicoideae, tribe Paniceae. Cytologia 41: 621–637.

COPE, T. A. 1982. Poaceae. *In:* E. Nasir & S. I. Ali (editors), Flora of West Pakistan 143: 1–678.

DUJARDIN, M. 1978. Chromosome numbers of some tropical African grasses from Western Zaire. Canad. J. Bot. 56: 2138–2152.

FARUQI, S. A., H. B. QURAISH & N. HALAI. 1979. Chromosome numbers and some morphological characteristics of some Andropogoneae from Pakistan. Cytologia 44: 585–605.

FEDOROV, A. A. (editor). 1974. Chromosome Numbers of Flowering Plants. Otto Koeltz Science Publishers, West Germany (reprinted).

GOLDBLATT, P. (editor). 1981. Index to Plant Chromosome Numbers 1975–1978. Monogr. Syst. Bot. Missouri Bot. Gard. 5: 1–553.

———. 1984. Index to Plant Chromosome Numbers 1979–1981. Monogr. Syst. Bot. Missouri Bot. Gard. 8: 1–427.

———. 1985. Index to Plant Chromosome Numbers 1982–1983. Monogr. Syst. Bot. Missouri Bot. Gard. 13: 1–224.

———. 1988. Index to Plant Chromosome Numbers 1984–1985. Monogr. Syst. Bot. Missouri Bot. Gard. 23: 1–264.

LÖVE, A. & D. LÖVE. 1961. Chromosome numbers of Central and Northwest European plant species. Opera Botanica 5: 1–581.

MALIK, C. P. & T. N. MARY. 1970. Chromosome Number Reports XXVII. Taxon 19: 437–442.

MEHRA, P. N. 1982. Cytology of East Indian Grasses. P. N. Mehra, Chandigarh.

MOORE, R. J. (editor). 1973. Index to Plant Chromosome Numbers for 1967–1971. Regnum Vegetabile 90: 1–539.

———. 1974. Index to Plant Chromosome Numbers for 1972. Regnum Vegetabile 91: 1–108.

ORNDUFF, R. (editor). 1967. Index to Plant Chromosome Numbers for 1965. Regnum Vegetabile 50: 1–128.

PARKASH, O. 1979. Cytological Investigations in Some Grasses of Northeastern India (Festucoids, *Ischaemum* Linn., *Eulalia* Kunth and *Saccharum spontaneum* Linn.). Ph.D. Thesis, Chandigarh.

RAMAN, V. S., P. CHANDRASEKHARAN & D. KRISHNASWAMI. 1959. Chromosome numbers in Gramineae. Curr. Sci. 28: 453–454.

SHARMA, M. L. 1985. Climato-geographic polyploidy variations in the Himalayan Grasses. Cytologia 50: 483–486.

STEBBINS, G. L. 1950. Variation and Evolution in Plants. Columbia Univ. Press, New York.

———. 1956. Cytogenetics and evolution of the grass family. Amer. J. Bot. 43: 890–905.